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EYE TRACKING PERFORMANCE VARIABILITY IN A HOMOGENEOUS POPULATION

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Smooth Pursuit Tracking, Ocular Tracking, Tracking Performance, Saccades, Eye Movements

Abstract

Pursuit tracking eye movements were recorded and analyzed from a group of US Air Force Pilot Candidates (PCs). The PCs ranged in age from 21 to 27 with a median age of 23. All were college graduates and recently passed a Flying Class I physical exam. These PCs comprise a highly motivated, intelligent group of young subjects. Pursuit tracking was assessed by having the subjects track a small spot of green light moving sinusoidally in the horizontal plane at frequencies from 0.2 to 1.0 Hz in 0.2 Hz increments. Peak-to-peak target amplitude was 40°. Eye movements were recorded using an infrared reflectance device. Eye movements were separated into smooth pursuit (SP) and saccadic (SA) components. Tracking performance was evaluated by computing the gain and asymmetry of the SP component and the percentage of tracking movements contributed by the SA component. Both mean values and variance of the tracking performance of the PCs were not found to be statistically different from a group consisting of both flying and nonflying Air Force personnel.

INTRODUCTION

Pursuit tracking eye movements continue to be a subject of considerable study. Recent articles describe various eye tracking tests as being useful for clinical evaluations [3, 4]. Other papers have reported the effects of aging on eye-tracking performance [5, 6, 7]. We have recently discussed pursuit eye tracking as a possible indicator of the types of sensory-motor skills required for flying [2]. One of the striking features of all these eye-tracking studies is the large degree of variability in the tracking skills of supposed normal subjects. If eye-tracking performance is to be used successfully as a diagnostic or classification tool, then it is important to establish a "normal range" for the performance parameters.

We recently had the opportunity to evaluate the eye-tracking performance of a number of US Air Force

pilot candidates (PCs). These PCs represent a very homogeneous group of highly motivated young subjects. The performance variability in this group should represent the lower limit of variability to be expected in any population that has not been preselected for tracking performance skills. The objective of this study was to determine the tracking performance and performance variability of this homogeneous subject group and compare their performance to a much broader range of subjects from a previous study [2].

METHODS

Subjects: A total of 34 subjects were tested. Subjects ranged in age from 21 to 27, median age 23. Four of the subjects were female. Subjects were all (PCs) and had passed a Flying Class I physical exam. All subjects were US Air Force Commissioned Officers and were tested just prior to entry into flight training. All participants were briefed as to the purpose of the research and the testing procedures to be used. The voluntary, fully informed consent of the subjects used in this research was obtained as required by AFR 169-6.

Apparatus: Subjects were instructed to track a small spot of green (543.5 nm) light moving sinusoidally in the horizontal plane while the movement of each eye was recorded. The target was generated by a 0.2-mW, He-Ne laser (Melles Griot Model 05-LGR-025). A General Scanning Industrial Laser Display Module provided the function of laser pointing and target movement. The target was projected onto a curved screen located 2 m in front of the subject. Target motion was sinusoidal, with a peak-to-peak amplitude of 40° and a frequency ranging from 0.2 to 1.0 Hz in increments of 0.2 Hz. Increasing target frequency corresponds to increasing levels of tracking difficulty. Head stabilization was provided by a bite bar. Eye movements were recorded using a modified version of the infrared reflectance device previously described by Engelken, *et al.* [1]. A Compaq DeskPro 386/33 computer equipped with Analog Devices RTI-800-A (A/D) and RTI-802-8 (D/A) boards was used to generate driving signal for the laser display module and digitize the eye-movement responses. The eye-movement signals were digitized to a resolution of 12 bits at a rate of 125 Hz. The eye-movement signals and the target position were stored in files on the hard disk for later analysis.

Testing Procedures: Subjects tracked 10 cycles of target movement at each frequency beginning at 0.2 Hz and progressing to 1.0 Hz with a 5 s pause between each of the 10 cycle epochs. The eye-movement recording system was calibrated before data collection by having the subjects fixate stationary targets at 5° intervals across the target movement range. A third-order polynomial was fit to the calibration data and used to linearize the recorder output.

Data Processing: Data processing procedures have previously been described in detail [2, 3] and will only be summarized here. The eye-movement recording system measured the eye position of each eye separately. The eye movement response to the moving target was termed the *total tracking response* (TTR). The TTR was separated into *smooth pursuit* (SP) and a *saccadic* (SA) components. The *gain* (the ratio of eye movement to target movement) of the TTR and SP components was calculated at each target movement frequency. The *tracking deficit* (TD) was also calculated at each test frequency. TD was defined as the percentage of the TTR contributed by the SA component. TD is a direct indicator of tracking performance and is perhaps the best single measure of eye tracking ability. A high TD indicates poor performance of the smooth pursuit tracking system.

Statistical Analysis: The results were statistically evaluated to determine if any significant left-eye, right-eye tracking differences were present. Then the tracking performance parameters were compared

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TABLE I. Total Tracking Response Gain
—Means and 95% Confidence Limits—

Frequency	—Lower 95%—	—Mean—	—Upper 95%—
0.2	0.968	1.029	1.091
0.4	0.950	1.032	1.114
0.6	0.918	1.014	1.111
0.8	0.859	0.991	1.122
1.0	0.747	0.941	1.138

to the performance of subjects from a previous study [2]. Finally, mean and 95% confidence values for future measurements were calculated for the PCs' performance parameters.

RESULTS

There were no significant differences between left-eye and right-eye tracking and no differences in tracking performance between the PCs and subjects from our previous study. The mean values and 95% confidence limits for future observations for TTR Gain, SP Gain, and TD were calculated. These results are presented in Tables I, II, and III. The TD from the current study is compared to the TD from our previous study [2] in Figure 1.

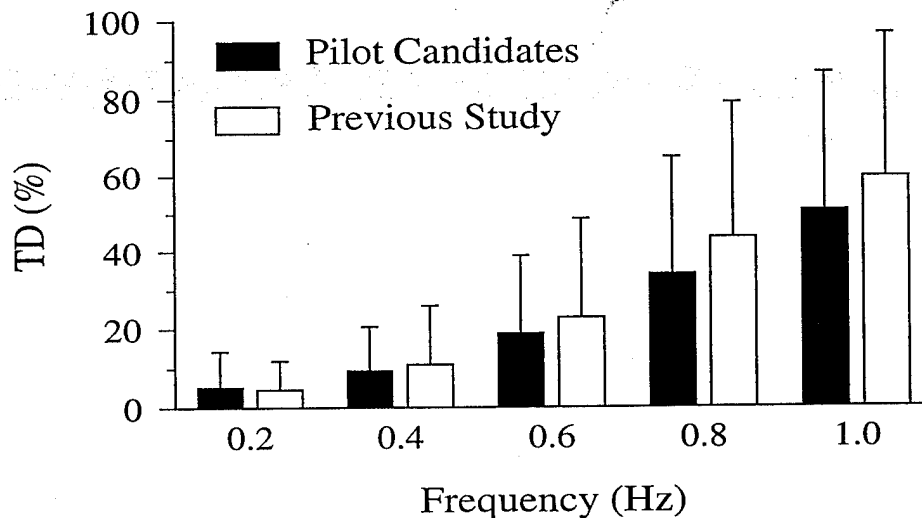


FIGURE 1. Mean Tracking Deficit and Upper 95% Confidence Limits as a function of Frequency.

DISCUSSION

Our previous studies [2, 3] and others [4, 5, 6, 7] have shown that eye-tracking performance is quite variable among normal subjects. We have studied a very homogeneous group of subjects (PCs) and confirmed that considerable variability is to be expected, even in a young, healthy population. We compared the

TABLE II. Smooth Pursuit Gain
-Means and 95% Confidence Limits-

Frequency	-Lower 95%-	-Mean-	-Upper 95%-
0.2	0.863	0.975	1.086
0.4	0.787	0.935	1.080
0.6	0.582	0.824	1.065
0.8	0.310	0.656	1.001
1.0	0.090	0.468	0.846

TABLE III. Tracking Deficit (TD)
-Means and 95% Confidence Limits-

Frequency	-Lower 95%-	-Mean-	-Upper 95%-
0.2	0.000	5.338	14.32
0.4	0.000	9.523	20.63
0.6	0.000	18.91	38.96
0.8	3.184	34.06	64.93
1.0	15.10	50.81	86.53

tracking performance of our PCs to a group consisting of 12 Air Force pilots and 11 nonfliers whose military rank ranged from airman to colonel. These subjects ranged in age from 25 to 49, median age was 36. Figure 1 shows the TD from these two subject groups. Except for 0.2 Hz, the TD for the PCs is slightly less than for the other group, but the differences were not statistically significant. The variability in performance (as evidenced by the 95% confidence limits in Figure 1) appears about the same for both groups. Indeed, statistical testing of the TTR gain, SP gain, and TD disclosed no significant differences in the variability of the two groups.

Periodic testing of our laboratory staff members over the years has demonstrated that the tracking performance of a given individual is constant and reproducible. Thus, we are confident that the variability observed in this study is truly *between* subject variability and not day-to-day variations *within* subjects. This intrinsic variability between individuals suggests that eye-tracking performance alone should be used with caution as a diagnostic or classification tool, at least until the significance of these individual differences are established. It is our intent to assess the tracking performance of at least 100 PCs and follow their progress through their flight training program. Correlating tracking performance with class standing and other flight training assessments may provide information as to relationship between eye-tracking skills and the skills required to fly high-performance aircraft.

The eye-tracking study described here is a part of an overall program to determine if various screening tests are useful in predicting the performance of the PCs during and after flight training. In addition to pursuit eye-tracking, we are also evaluating the vestibulo-ocular reflex, the optokinetic reflex, and the saccadic eye-movement system. The results of these studies will be reported at a later time.

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